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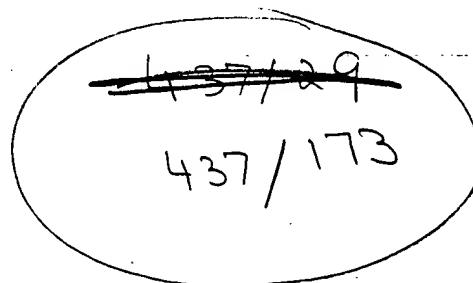
86-107811/17 FUJITSU LTD 17.01.85-JP-006221 (+JP-211703) (23.04.86) H011-21/20 H011- 29/78 Mfg. semiconductor devices by semiconductor-on insulator technology - by irradiating layer through windows in anti reflection film to form recrystallised areas C86-046004 E(DE FR GB)	L03 U11 (U12) FUIT 09.10.84 *EP -178-447-A high device yield. <u>SPECIFICALLY</u> Insulated gate electrode is formed in a recrystallised area, with source and drain regions formed abutting the area. The electrode insulating layer is $\text{SiO}_2$ , pref. formed using LPCVD or thermal oxidn. Irradiation beam is a laser, esp. an Ar ion laser, scanned over the anti-reflecting layer so that the regions in the windows are consecutively recrystallised.(29pp1550KJP DwgNo0/5). (E)ISR: No Search Report.
The device is mfd. by: (i) forming an amorphous or poly semiconductor layer on an amorphous insulating layer; (ii) adding an anti-reflecting film; (iii) forming windows in the film; (iv) irradiating to recrystallise the layer in the windows; and (v) forming devices or active regions in the recrystallised areas. Semiconductor is specifically Si; anti-reflecting layer is $\text{Si}_3\text{N}_4$ or $\text{SiO}_2/\text{Si}_3\text{N}_4$ .	USE In an IGFET device in which the channel region is formed in the recrystallised area. (claimed).
<u>ADVANTAGE</u> Device areas can be formed with random layout and with	EP-178447-A

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Recrystallize w/ cap layer



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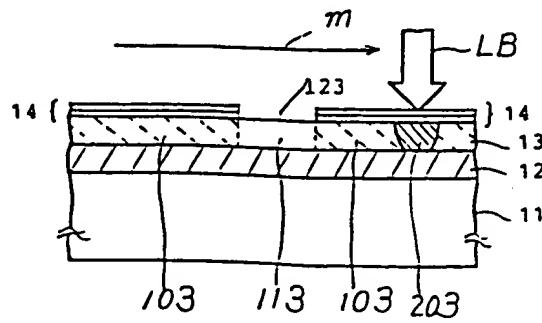
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(54) A manufacturing method of an integrated circuit based on the semiconductor-on-insulator technology and a device so manufactured.

(57) Random layout of devices or active regions of the devices is allowed for a semiconductor integrated circuit based on an SOI technology using an anti-reflecting film (14). Openings (123) are provided for the anti-reflecting film (14) formed on a polycrystalline silicon layer (13), corresponding to the device regions wherein devices or active regions of the devices are to be formed. An overlapped scan of a laser (LB) beam having diameter larger than the dimension of the openings (123) is applied on the silicon layer (13) through the openings and circumferential anti-reflecting film (14). Concaved temperature profile is achieved along every directions (m) across the openings due to the enhanced beam (LB) absorption by the circumferential anti-reflecting film (14), hence recrystallization nucleation of the silicon layer initiates at the center of each opening during the laser beam scan. Thus, self-aligned single crystal regions (113) are fabricated in the polycrystalline silicon layer (13) at the respective predetermined device regions. The channel region of an IG-FET is exclusively formed in the single crystal region (113) and the source or drain regions are formed in adjacent polysilicon regions.

FIG. 4(c)



see front page

TITLE OF THE INVENTION

A Fabrication Method of a Semiconductor Integrated Circuit  
and a Device Fabricated by Using the Same

BACKGROUND OF THE INVENTION

The present invention relates to a semiconductor device based on so-called SOI (semiconductor on insulator) technology, particularly to a method for fabricating the semiconductor device by using an anti-reflecting film for laser beam irradiation.

SOI technology has been receiving increasing interests because of its attractive capabilities of providing integrated circuits (ICs) with increased breakdown voltages between isolated circuit components such as transistors and so forth, and also with improved operating speeds due to reduced parasitic capacitances between the circuit components and a substrate the circuit components formed thereon. The outstanding feature of SOI technology is the capability of providing three-dimensional ICs considered as the most promising means of breakthrough for the limitation to the integration density in conventional ICs.

In the early stage of SOI technology, efforts were directed to obtaining a recrystallized region as large as possible in a polycrystalline semiconductor layer such as a polysilicon layer. This resulted in the difficulty of forming a grain boundary free region at desired position in the semiconductor layer. If a grain boundary locates in

1       the active region of a transistor, for example, formed in  
          the recrystallized region, characteristics of the  
          transistor cannot be comparable to ordinary transistors  
5        fabricated on single crystal silicon substrates. Such  
          grain boundary becomes the causes of increased leakage  
          currents and nonuniformity of threshold voltages of the  
10      transistors.

Recent development in the SOI technology rather seems  
to be concentrated to selective recrystallization of an  
amorphous or polycrystalline semiconductor layer. That is,  
only predetermined regions of a semiconductor layer, in  
each of which an active component such as transistor is to  
be formed, are recrystallized into single crystal islands.  
Though originally proposed for increasing efficiency of the  
light beam irradiation for recrystallizing a semiconductor  
layer, anti-reflecting film coating has been reported to be  
advantageous for such selective recrystallization if it is  
modified into a stripe structure. (Colinge et al; Applied  
Physics Letters, vol.41, p.346, 1982). In this method,  
transversely arranged stripes of anti-reflecting film are  
formed on a amorphous or polycrystalline silicon layer. A  
laser beam having diameter large enough to cover at least  
two adjacent stripes is scanned along the center line  
between the stripes. The laser beam energy is controlled  
to be at slightly above the lowest level necessary for  
melting the uncoated region of the silicon layer. Thus, a  
desired concaved temperature profile in the lateral

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direction can be achieved thanks to the greater beam absorption by the stripes of anti-reflecting film. This method will be described in some detail in the following.

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FIGs.1(a) and 1(b) are schematic illustrations of an amorphous or polycrystalline silicon layer and stripe-structured anti-reflecting films successively formed on an amorphous insulating layer, wherein FIG.1(a) is a plan view and FIG.1(b) is a cross-section taken along the line B-B in FIG.1(a).

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Referring to FIG.1(a) and 1(b), an amorphous or polycrystalline silicon layer 22, which is to be recrystallized into a single crystal, is deposited on an amorphous insulating layer 21. An anti-reflecting film 23 of silicon nitride,  $\text{Si}_3\text{N}_4$ , is formed on the silicon layer 22, and then, delineated into stripe structures 23 as shown in FIGs.1(a) and 1(b). If thickness of the anti-reflecting film stripes 23 is adequately controlled, the reflectivity of the surface of the silicon layer 22 at the region coated with the stripe 23 can approximately be 5% in contrast to that of 60% at the uncoated region. As a result, when a irradiation or laser beam, an argon ion laser beam, for example, having a spot diameter larger than the distance between the stripes 23 is applied, temperature distribution profile as shown in FIG.1(c) is obtained in the lateral direction (i.e. the direction along B-B line in FIG.1(a)).

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In FIG.1(c), ordinate indicates temperature T and abscissa indicates the position between the stripes 23. As shown in

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FIG.1(c), the temperature T is lowest at the center of the stripes 23.

5        When a laser beam is scanned along the center line between the stripes 23 in the direction as indicated by the arrow in FIG.1(a), recrystallization front edges in the silicon layer is schematically indicated by a curve 25 which moves upward according to the scanning of the laser beam. In FIG.1(a), two curves 25 correspond to respective recrystallization fronts at two different moments. Each of the curves 25 indicates a solid-liquid interface and melting point of the silicon layer 22 distributes along the curve 25. Because the curve 25 (solid-liquid interface line) has curvature bending behind the front edge, the growth of a crystal grain nucleated from a virtual seed on the center line is dominant, and finally, spreads over the region between the stripes 23. As a result, grain boundaries between the above mentioned dominant grain and other subdominant grains are going to be swept from the region between the stripes 23 and accumulate under the stripes 23. Similar concaved temperature profile is obtained by using a doughnut-shaped laser beam and successful recrystallization is achieved in a polysilicon layer on an amorphous layer. (Kawamura et al; Applied Physics Letters, vol.40, p.394, 1982)

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35        Thus, with the use of anti-reflecting film stripes, it is reported that a single crystallized region of 20x100 square microns can be formed in a silicon layer on an

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amorphous insulating layer. The stripe-structured  
anti-reflecting film permits laser beam to be efficient and  
simple of its shape as a round beam. However, the  
stripe-structured anti-reflecting film methodology  
inevitably decreases the freedom in the device pattern  
layout on a semiconductor layer.

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Referring to FIGs.1(a) and 1(b), if devices such as  
transistors or at least active regions of the devices are  
respectively located in regions 26a and 26b of the  
semiconductor layer 22, one of the devices or active

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regions of the devices can be formed in a  
single-crystallized region 26a, but another formed in a  
region 26b can not be free of a grain boundary because of  
the reason as described before. Since grain boundaries

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provide the device with the aforesaid undesirable  
influences, the device pattern layout can not but be  
restricted within the region between the anti-reflecting  
film stripes 23. This means that random layout of the  
devices or active regions of the devices is substantially  
inhibited and the devices or the active regions must be  
positioned in a relatively orderly arrangement instead.

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As a result, SOI technology using anti-reflecting film  
stripes is suitable to integrated circuits (ICs) such as  
those based on gate array methodology but is rather not  
suitable to ICs requiring random arrangement of devices as  
in logic ICs. Thus, the anti-reflecting film stripe

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methodology also restricts efficient use of semiconductor area in ICs based on SOI.

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SUMMARY OF THE INVENTION

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It is an object of the present invention to provide a semiconductor integrated circuit based on an SOI technology using an anti-reflecting film, wherein the layout of devices on a semiconductor layer can be substantially random.

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It is another object of the present invention to provide a semiconductor integrated circuit based on an SOI technology using an anti-reflecting film, wherein effective use of semiconductor area can be achieved.

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It is further another object of the present invention to provide an insulated-gate transistor based on an SOI technology with improved fabrication yield.

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The above objects can be attained by fabricating a semiconductor integrated circuit based on an SOI technology using an anti-reflecting layer but not in the form of stripes. The fabrication method comprising steps of: (a) forming an amorphous or polycrystalline semiconductor layer on an amorphous insulating layer; (b) forming an anti-reflecting film to a light beam on the semiconductor layer; (c) selectively forming openings at respective predetermined portions of the anti-reflecting film; (d) irradiating the light beam to an area of surface of the anti-reflecting film, the area including at least one of

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the openings, on conditions that the semiconductor layer is recrystallized to be free of grain boundaries at the opening; and (e) forming a semiconductor device or active region of the device in the recrystallized semiconductor layer at the opening. In accordance with the method, the channel region of an insulated-gate field effect transistor (IG-FET) or metal oxide semiconductor (MOS) transistor is exclusively formed in a recrystallized semiconductor layer at the opening.

BRIEF DESCRIPTION OF DRAWINGS

The above and other objects and advantages of the present invention will become apparent from the following description of embodiments with reference to accompanying drawings forming a part thereof, wherein:

FIGS.1(a) and 1(b) are schematic illustrations of an amorphous or polycrystalline silicon layer formed on an amorphous insulating layer and stripes of anti-reflecting layer formed on the silicon layer, wherein FIG.1(a) is a plan view and FIG.1(b) is a cross-section taken along the line B-B in FIG.1(a);

FIG.1(c) is a temperature distribution profile obtained in the direction along B-B line in FIG.1(a);

FIGS.2(a) and 2(b) are a plan view and enlarged cross-section taken along line B-B in FIG.2(a) in accordance with an embodiment of the present invention.

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FIG.3(a) is a plan view schematically illustrating the growth of single recrystallized region at an opening according to the present invention;

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FIGs.3(b) and 3(c) are respective temperature distribution profiles on the lines E-E and F-F in FIG.3(a);

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FIGs.4(a) to 4(g) are cross-sections at the respective fabrication steps of a semiconductor device based on an SOI technology; and

FIGs.5(a) to 5(d) show yet another embodiment of the present invention.

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#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

An embodiment of the present invention is shown in a plan view of FIG.2(a) and an enlarged cross-section of FIG.2(b) taken along line B-B in FIG.2(b). Referring first to FIG.2(b), as a substrate, an insulating layer of  $\text{SiO}_2$  layer 4 of thickness of about 1 micron is formed on a silicon wafer 3 by using a thermal oxidation process, for example. Respective one of silicon nitride layer 5 and polysilicon layer 6 having thicknesses of 1000 Å and 4000 Å, respectively, are successively formed on the  $\text{SiO}_2$  layer 4 by using low pressure chemical vapor deposition (LPCVD) methods, for example. The polysilicon layer 6 is the layer to be subject to a recrystallization process later, and the silicon nitride layer 5 is for improving adhesion of the polysilicon layer 6 to the  $\text{SiO}_2$  layer 4 after the recrystallization. A  $\text{SiO}_2$  layer 7 of about 300 Å is formed

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by thermally oxidizing the surface of the polysilicon layer 6 and then a silicon nitride layer 8 of about 300 Å is deposited thereon by using an LPCVD method, for example. The SiO<sub>2</sub> layer 7 and silicon nitride layer 8 constitute anti-reflecting film 2 in FIG.2(a). The thickness of the anti-reflecting film 2 is determined according to the wave length of laser beam for the recrystallization and the refractive index of the layer materials to the wave length. The anti-reflecting film may comprises a single layer of either of SiO<sub>2</sub> or silicon nitride, however, the double-layered structure of the anti-reflecting film allows to take advantages as described in later.

Referring back to FIG.2(a), the anti-reflecting layer 2 is provided with substantially rectangular-shaped openings (windows) 1a, 1b, 1c and so forth, instead of being formed into the stripe structure in the prior art as shown in FIGs.1(a) and 1(b). Each of the openings is positioned so as to correspond to a device region (the region in which a device such as transistor or the active region such as channel region of the transistor is formed). The dimension of the opening is 10 to 20 microns, for example.

A light beam from a cw (continuous wave) Ar ion laser, for example, having output power of 8 to 14 watts is scanned over the anti-reflecting film 2 and the polysilicon layer at the openings 1a, 1b, 1c and so forth at a speed of 5 cm/sec. The scan of the laser beam is carried out by

1 translating the wafer 3 relative to a fixed beam or it may  
be done vice versa, wherein scanning pitch is controlled to  
5 be smaller than the diameter of the beam D so that the  
traces of the scanned beam overlap each other. A  
preferable overlap ratio is approximately 70 per cent of  
the beam diameter. The beam diameter D is 80 to 100  
10 microns in terms of the width of irradiated region on the  
substrate. The dimension of an opening is 10 to 20 microns  
as mentioned before. Hence, since the beam is relatively  
15 larger than the openings (4 to 10 times) and the scanning  
speed is relatively high compared with the dimension of  
openings, the polysilicon layer at each opening can be  
assumed to be heated with a pulse of a fixed beam. In the  
20 above, the beam for the recrystallization should not be  
limited to a laser beam but other energy beam such as a  
focused emission of a mercury lamp may be employed if it  
can provide a sufficient energy density.

25 FIG.3(a) is a plan view schematically illustrating the  
growth of single recrystallized region in an opening, for  
example, the opening 1a in FIG.2(a). FIGS.3(b) and 3(c)  
are temperature distribution profiles along the lines E-E  
30 and F-F in FIG.3(a), respectively, wherein T indicates  
temperature and coordinates on the respective axes  
perpendicular to the temperature axes indicate the position  
on lines E-E and F-F. The same as in the prior art using  
35 stripe-structured anti-reflecting film as described with  
reference to FIGS.1(a) to 1(c), the temperature T is lowest

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at the center of the opening 1a in both E-E and F-F directions and increases toward the periphery of the opening 1a because of the greater absorption of the laser beam irradiation by the anti-reflecting film 2. As a result, recrystallization of the polysilicon layer initiates from the nucleus 9 at the center of the opening immediately after the cease of the pulsed laser beam irradiation. A substantially isotropic recrystallization occurs to spread as shown by circles 10 in FIG.1(a), and finally, fills in the opening 1a. Thus, a grain-boundary-free single crystal polysilicon layer is formed in the opening 1a, and similarly in other openings.

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Another embodiment of the present invention will be described in the following with reference to FIGs.4(a) to 4(g) illustrating cross-sections at the respective fabrication steps of a semiconductor device based on SOI technology.

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Referring to FIG.4(a), a  $\text{SiO}_2$  insulating layer 12 of thickness of about 1 micron is formed on a silicon substrate 11 by using a thermal oxidation process, and then, an amorphous or polycrystalline silicon layer 13 of thickness of about 4000 Å is deposited on the insulating layer 12 by using a CVD (chemical vapor deposition) method. In the following description of this embodiment, a polysilicon layer stands for the silicon layer 13. The polysilicon layer 13 is then doped with a predetermined concentration of boron, B, as a p-type impurity by an ion

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implantation technique. Thus, the polysilicon layer 13 is provided with p-type conductivity.

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A  $\text{SiO}_2$  thin film 121 of thickness of about  $300 \text{ \AA}$  is formed on the polysilicon layer 13 by using a thermal oxidation process, and then a silicon nitride ( $\text{Si}_3\text{N}_4$ ) film 122 of thickness of about  $300 \text{ \AA}$  is deposited on the  $\text{SiO}_2$  film 121 by a CVD method. The  $\text{SiO}_2$  film 121 and  $\text{Si}_3\text{N}_4$  film 122 are selectively removed as shown in FIG.4(b) by using a conventional photolithographic technique so that openings throughout the films are formed at predetermined regions Ach. Each of the regions is referred to as device region in which an insulated gate field effect transistor (IG-FET) or at least the channel of the transistor is to be formed. In FIG.4(b), only one opening 123 is illustrated.

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The  $\text{SiO}_2$  film 121 and  $\text{Si}_3\text{N}_4$  film 122 constitutes an anti-reflecting film to the laser beam irradiation. The anti-reflecting film may comprise either one of  $\text{SiO}_2$  or  $\text{Si}_3\text{N}_4$  film as mentioned before, however, the double-layered anti-reflecting film as shown in FIG.4(b) permit to take advantage of large etching rate difference between  $\text{SiO}_2$  and  $\text{Si}_3\text{N}_4$  or silicon to etchants such as carbon tetra-fluoride ( $\text{CF}_4$ ) gas and a hydrochloric acid (HF) solution. For instance, during a dry etching process for forming the opening 123, the  $\text{SiO}_2$  film 121 having a relatively low etching rate compared with those of the  $\text{Si}_3\text{N}_4$  film 122 and polysilicon layer 13 plays a role of a stopping layer against the etching by an etchant gas such as  $\text{CF}_4$  but it

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can easily be removed by HF solution without affecting the polysilicon layer 13. Thus, the process for forming precision openings 123 in the anti-reflecting film on the polysilicon layer 123 can be facilitated.

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10 During the substrate 11 is heated at about 450°C in atmospheric air, scan of a laser beam LB, Ar ion laser, for example, in the direction of an arrow m is applied to the polysilicon layer 13 through the anti-reflecting film 14 as shown in FIG.4(c). Hence, every portions of the polysilicon layer 13 are brought into a molten state once  
15 according to the scan of the laser beam, and its corresponding region to the opening 123 is recrystallized into a single crystal 113. In FIG.4(c), references 103 and 203 designate a domain recrystallized into a polycrystalline state and that in molten state,  
20 respectively.

25 Intensity and scanning speed of the laser beam LB are controlled to be enough for melting the polysilicon layer 13 under the anti-reflecting film 14 which decreases the reflectivity of the surface of the polysilicon layer 13 to about 5 per cent but insufficient for melting a polysilicon 0 layer alone having surface reflectivity of about 60 per cent alone. (i.e. the laser beam is too weak to raise the polysilicon layer 13 at the opening 123 up to the melting point if no anti-reflecting layer 14 is formed around the 5 opening 123.) Exemplary conditions complying with such requirement are as follows:

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Laser output: 10 Watts

Laser beam diameter: 50 microns

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Scanning speed: 5 cm/sec

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In the above, the laser beam diameter is defined in terms of the width of melted region of a polycrystalline layer coated with an anti-reflecting film when a laser beam is scanned thereon.

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With the scan of a laser beam under the above conditions, recrystallization of the polysilicon layer 13 initiates at the center of the opening 123 and spreads therein as explained with reference to FIG.3 (a). Thus, the polysilicon layer 13 at the opening 123 becomes single crystal, however, desirable recrystallization into a single crystal layer does not occur in the circumferential polysilicon layer 13 under the anti-reflecting film 14 as mentioned before.

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In accordance with the object of the present invention, a number of openings in an anti-reflecting film can be positioned randomly, corresponding to the regions, each for forming a device or active region of the device therein. As a result, it is probable that when a laser beam is scanned with aforesaid overlapping manner, the edge of the laser beam occasionally crosses over an opening at which the polysilicon layer has already been single-crystallized. However, the single-crystallized layer in the region would not be melted again by the laser beam scan, because heat necessary for the

1           single-crystallized region to reach again its melting point  
5           is not supplied from the un-irradiated side region of the  
         opening.

10          After the polysilicon layer 13 at each opening 123 is  
         recrystallized to be grain boundary free (whereas each  
         corresponding circumferential region is recrystallized as a  
         polycrystal layer), the  $\text{Si}_3\text{N}_4$  film 122 and  $\text{SiO}_2$  film 121  
         constituting the anti-reflecting film 14 are removed by  
         using a hot phosphoric acid solution and a hydrofluoric  
         acid solution, respectively. Then, the polysilicon layer  
15          13 is formed into islands so that each island includes one  
         of the single-crystallized region 113 and corresponding  
         polycrystalline circumferential region 103, as shown in  
         FIG.4(d).

20          The surface of the island is thermally oxidized, hence  
         a gate oxide layer 15 having a predetermined thickness is  
         formed as shown in FIG.4(e). Subsequently, a polysilicon  
25          layer of thickness of about  $4000 \text{ \AA}$  is formed on the island  
         by a conventional CVD process and selectively etched by  
         using an ordinary photolithographic technique so that a  
         gate electrode 16 is left on the single-crystallized region  
30          113.

35          Following the above, high concentration of an impurity  
         such as arsenic (As) is ion-implanted into the silicon  
         layer 103 with the use of polysilicon gate electrode 16 as  
         a mask, hence  $n^+$ -type source or drain regions 17 and 18 are  
         formed after an annealing at temperature  $1050^\circ\text{C}$ , as shown

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in FIG. 4(f). Thus, basic structure of an insulated-gate field effect transistor (IG-FET) or MOS transistor is completed based on SOI technology.

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An insulating coating layer 19 is formed on each of the transistor structure. The insulating coating layer 19 having thickness of about 8000 Å is, then, provided with contact holes 100 through which connections to the source or drain regions 17 and 18 are provided by the respective wiring layers 110 and 120 of aluminum, for example, as shown in FIG. (g). If a PSG (phospho-silicate glass) layer is used for the insulating coating layer 19, a heat process (conventionally referred to as a reflow process) at 1050°C, for example, is needed for blunting the sharp edge of the contact holes 100.

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As described above, a heat process at a temperature as high as 1050°C is necessary for the annealing of the ion-implanted source or drain regions 17 and 18 or the reflow process for the contact holes 100 in a PSG layer. The heat process at such high temperature tends to cause diffusion of doped impurities from the source or drain regions 17 and 18 to the single crystal region 113. If a grain boundary should exist in the single crystal region 113, the impurity diffusion along the grain boundary would be accelerated, and thus, the problems in the prior art, such as increased leak currents, non-uniform threshold voltages, source-drain breakdown failures, etc. in the

1 devices formed in the recrystallized semiconductor layer,  
would occur.

5 Again, in the prior art SOI technology using  
anti-reflecting film, it is substantially impossible to  
recrystallize a semiconductor layer selectively only at the  
device regions. As a result, the regions to be grain  
boundary free are formed inevitably large in order to  
10 provide some degree of freedom in the arrangement of the  
devices. This results in difficulty in the fabrication and  
poor yield of semiconductor integrated circuits based on  
15 the SOI technology. On the other hand, according to the  
present invention, it is possible to recrystallize a  
semiconductor layer at arbitrary regions corresponding to  
the device regions, as explained in the above embodiments.  
20 As a result, small semiconductor regions, each of which  
afford to accommodate at least the active region of a  
device, for example, a channel region of an IG-FET, can  
selectively be grain boundary free, corresponding to the  
25 device layout. Thus, according to the present invention,  
the IG-FETs, for example, in a semiconductor integrated  
circuit based on an SOI technology can be free from the  
prior art problems relating to the grain boundaries, and  
30 therefore, superior characteristics and greater fabrication  
yield of the integrated circuit can also be provided. It  
is obvious that entire region of a device including the  
35 source or drain regions of an IG-FET, for example, can be  
fabricated in a grain-boundary-free region formed according

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1 to the present invention, since the grain-boundary-free  
region can be large as 10x20 square microns.

5 FIGS.5(a) to 5(d) show further another embodiment of  
the present invention. A polycrystalline semiconductor  
layer 41, polysilicon layer, for example, having thickness  
10 of about 4000 Å is formed on an insulating layer 40 having  
thickness of about 1 micron, and an anti-reflecting film 42  
having an opening 421 is formed on the polysilicon layer  
15 41, as shown in FIG.5(a). The anti-reflecting film 42 may  
has a double-layered structure comprising a  $\text{Si}_3\text{N}_4$  layer 422  
and an underlying  $\text{SiO}_2$  layer 423, each having a thickness  
of about 300 Å. The polysilicon layer 41 at the opening  
20 421 is recrystallized to be grain boundary free by a laser  
beam irradiation, as described in the previous embodiments.  
The surface of the polysilicon layer 41 at the opening 421  
25 is thermally oxidized to form a  $\text{SiO}_2$  layer 411 of thickness  
of about 1000 Å. The anti-reflecting film 42 protects the  
polysilicon layer 41 around the opening 421 from the  
thermal oxidation.

The  $\text{Si}_3\text{N}_4$  layer 422 of the anti-reflecting film 42 is  
removed by using a selective etchant such hot phosphoric  
30 acid solution. The  $\text{SiO}_2$  layer 411 and the exposed  $\text{SiO}_2$   
layer 423 as shown in FIG.5(b) are subjected to a dry  
etching process using an etchant such as  $\text{CF}_4$  plasma. The  
time necessary for etching off the 300 Å  $\text{SiO}_2$  layer 423 is  
35 about 40 seconds and that for the 1000 Å  $\text{SiO}_2$  layer 411 is  
about 120 seconds. Hence, the surface of the polysilicon

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layer 41 around the opening 421 is first exposed to the  $\text{CF}_4$  plasma, and subsequently etched off completely before the remaining about 700 Å  $\text{SiO}_2$  layer 411 is etched off, as shown in FIG.5(c), because etch rate of silicon by  $\text{CF}_4$  plasma is about 100 times larger than that of  $\text{SiO}_2$ . The dry etching is continued until the  $\text{SiO}_2$  layer 411 is just removed, and finally, a single crystal island 412 of silicon is left on the insulating layer 40, as shown in FIG.5(d). Thus, self-aligned single crystal silicon islands can be obtained in accordance with the SOI technology of the present invention.

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While the described embodiments represent the preferred form of the present invention, it is to be understood that modifications will occur to those skilled in the art without departing from the spirit of the invention. The scope of the present invention is therefore to be determined by the appended claims.

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CLAIMS

5        1. A fabrication method of a semiconductor device,  
comprising the steps of:

10              forming an amorphous or polycrystalline semiconductor  
layer on an amorphous insulating layer;

15              forming an anti-reflecting film to a light beam on  
said semiconductor layer;

20              selectively forming openings at respective  
predetermined portions of said anti-reflecting film;

25              irradiating said light beam to an area of surface of  
said anti-reflecting film, said area including at least one  
of said openings, on conditions that said semiconductor  
layer is recrystallized to be free of grain boundaries at  
said opening; and

30              forming a semiconductor device or active region of  
said device in said recrystallized semiconductor layer at  
said opening.

35        2. A fabrication method of a semiconductor device as set  
forth in claim 1, wherein said semiconductor is silicon.

40        3. A fabrication method of a semiconductor device as set  
forth in claim 1, further comprising a step of forming an  
insulated gate electrode on said recrystallized region of  
45        said semiconductor layer, said insulated gate electrode  
comprising a gate electrode and an insulating layer formed

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between said gate electrode and said recrystallized region of said semiconductor layer.

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4. A fabrication method of a semiconductor device as set forth in claim 3, further comprising a step of forming respective regions for source and drain in said semiconductor layer, said source and drain regions facing each other across said recrystallized region of said semiconductor layer and abutting said recrystallized region.

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5. A fabrication method of a semiconductor device as set forth in claim 3, wherein said semiconductor is silicon.

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6. A fabrication method of a semiconductor device as set forth in claim 5, wherein said insulating layer is a silicon dioxide layer.

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7. A fabrication method of a semiconductor device as set forth in claim 6, wherein said silicon dioxide layer is formed by using LPCVD (low pressure chemical vapor deposition).

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8. A fabrication method of a semiconductor device as set forth in claim 6, wherein said insulating silicon dioxide layer is formed by thermally oxidizing the surface of said recrystallized region of said semiconductor layer.

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9. A fabrication method of a semiconductor device as set forth in claim 1, wherein said anti-reflecting layer comprises a silicon nitride layer.

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10. A fabrication method of a semiconductor device as set forth in claim 9, wherein said anti-reflecting layer further comprises underlying silicon dioxide layer.

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11. A fabrication method of a semiconductor device as set forth in claim 1, wherein said light beam is a laser beam.

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12. A fabrication method of a semiconductor device as set forth in claim 11, wherein said laser beam is an Ar ion laser beam.

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13. A fabrication method of a semiconductor device as set forth in claim 1, wherein said light beam is scanned over said anti-reflecting layer so that semiconductor regions at said openings are consecutively recrystallized.

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14. An insulated-gate field-effect transistor (IG-FET) fabricated in a semiconductor layer formed on an amorphous insulating layer (24, 4, 12, 40), said semiconductor layer (22, 6, 13, 41) having a recrystallized region in which channel region of said IG-FET is exclusively formed.

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FIG. 1(a)

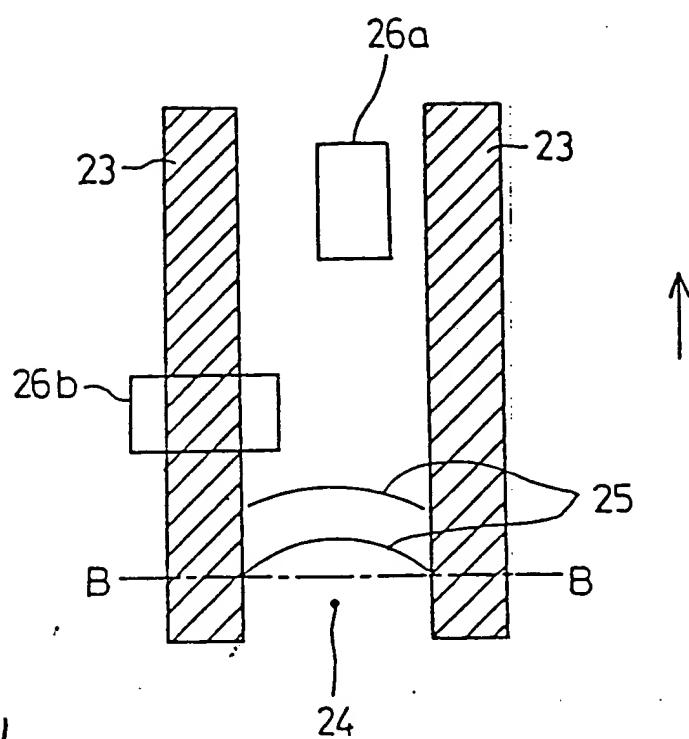


FIG. 1(b)

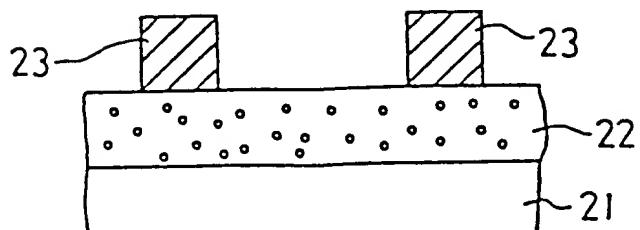


FIG. 1(c)

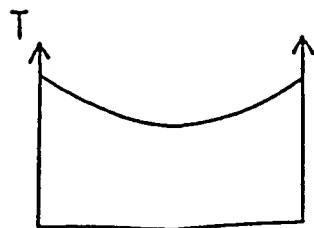


FIG. 2(a)

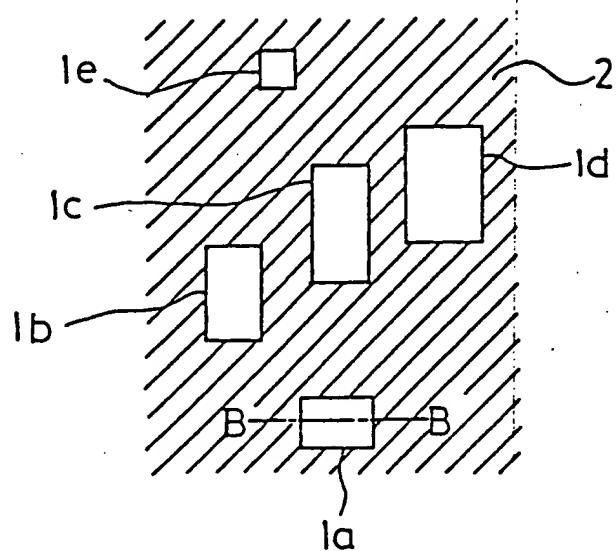
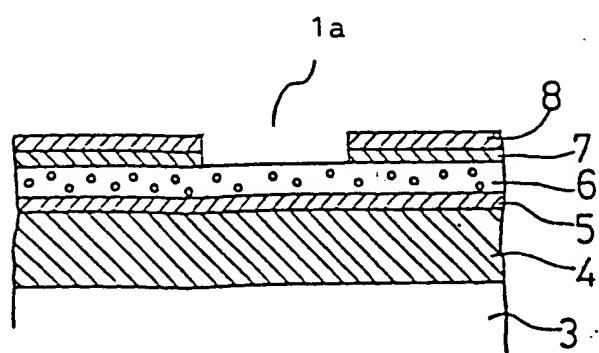


FIG. 2(b)



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FIG. 3(a)

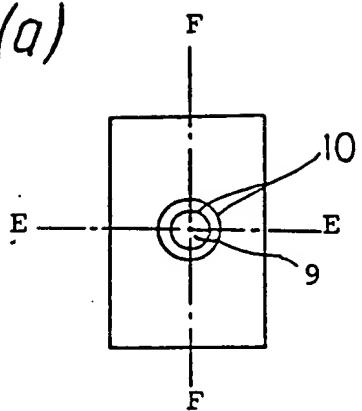


FIG. 3(c)

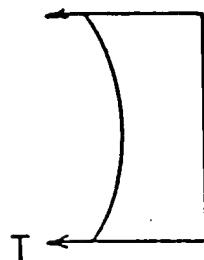


FIG. 3(b)

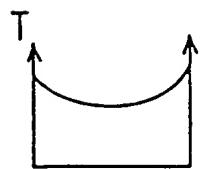


FIG. 4(a)

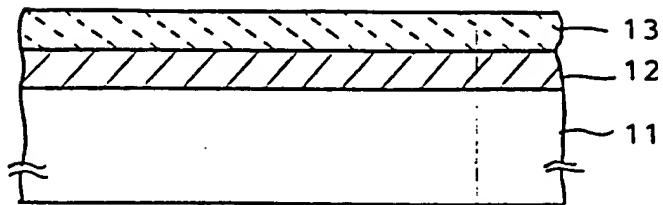


FIG. 4(b)

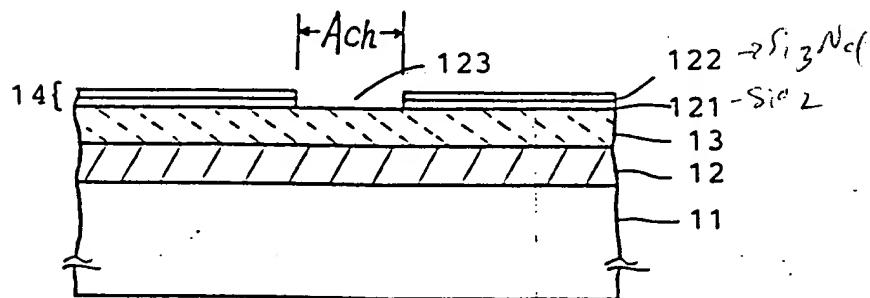


FIG. 4(c)

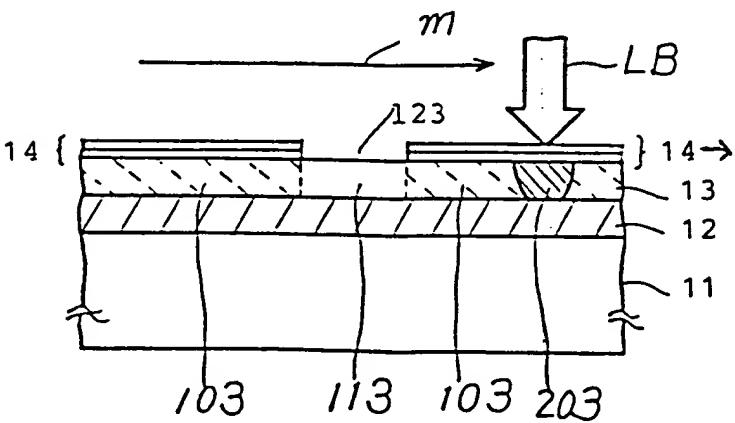
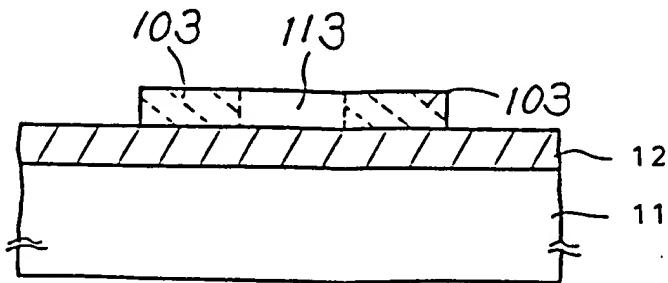


FIG. 4(d)



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FIG. 4 (e)

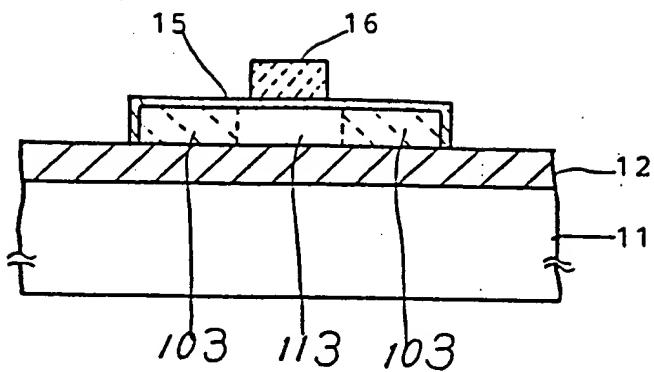


FIG. 4 (f)

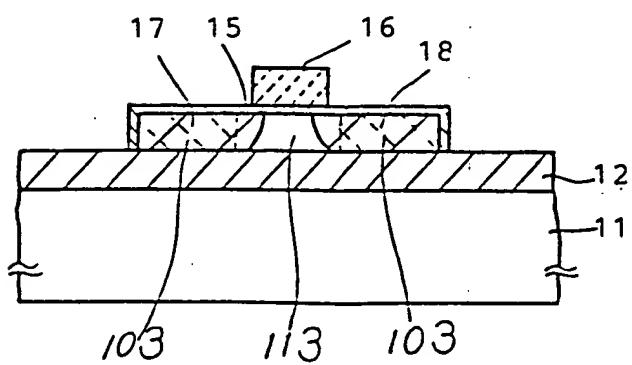


FIG. 4 (g)

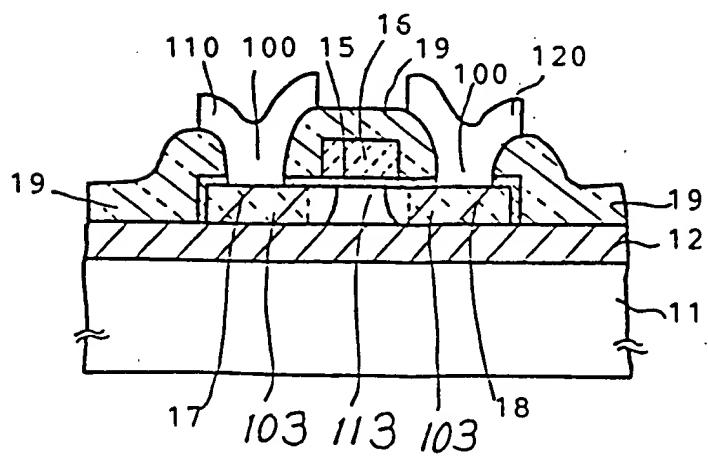


FIG. 5(a)

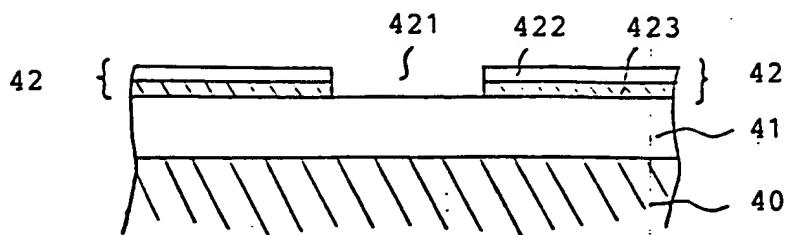


FIG. 5(b)

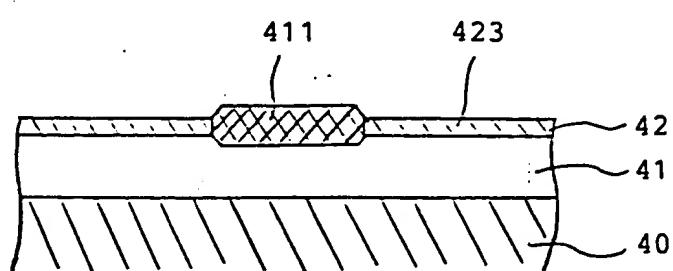


FIG. 5(c)

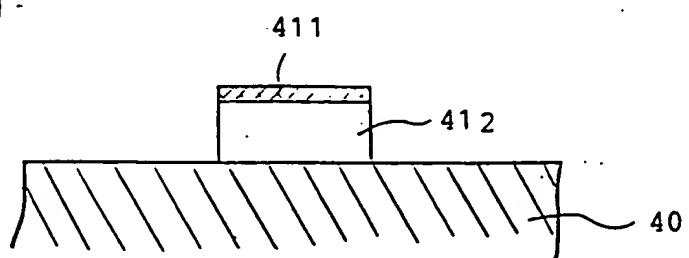


FIG. 5(d)

